APPARATUS AND METHOD FOR TRANSMITTING/RECEIVING DIFFERENTIAL STBC USING CHANNEL POWER

5   **PRIORITY**

This application claims priority under 35 U.S.C. § 119 to an application entitled "Apparatus and Method for Transmitting/Receiving Differential STBC Using Channel Power" filed in the Korean Intellectual Property Office on April 10 25, 2003 and assigned Serial No. 2003-26265, the contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

15   1.   Field of the Invention

The present invention relates generally to a wireless communication system, and in particular, to a transmission/reception apparatus and method using transmit antenna diversity to cope with signal degradation caused by fading.

20   2.   Description of the Related Art

Transmit diversity is one of the many effective technologies designed for relieving fading in a wireless communication system. Typical transmit diversity technology detects desired data symbols using a channel characteristic from a transmitter to a receiver. However, because of the mobility and variation of a 25 channel, it is impossible to correctly detect a channel characteristic between a transmitter and a receiver. Further, feeding back channel state information to the transmitter undesirably results in a reduction in the channel capacity. Therefore, a large amount of research has been conducted on transmit diversity for the case where a transmitter has no channel information.

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Recently, space-time block coding (STBC) has attracted a great deal of public attention because it provides good performance when a high data rate is required. In particular, *Tarokh et al.* proposes a space-block trellis code capable of obtaining both good coding gains and diversity gains when a plurality of 5 antennas are used (see Vahid Tarokh, Et al. "Space time block coding from orthogonal design," IEEE Trans. on Info.. Theory, Vol.45, pp. 1456-1467, July 1999). Here, the diversity gain corresponds to a reduction in channel gain generated by a fading channel.

10 FIG. 1 is a block diagram illustrating a conventional transmitter using a space-time block code (STBC). As illustrated in FIG. 1, the transmitter includes a serial-to-parallel (S/P) converter 10, an encoder 20, and N transmission antennas 30-1, 30-2, ⋯, 30-N.

15 Referring to FIG. 1, the S/P converter 10 creates a block of symbols by grouping symbols received from a predetermined information source (not shown) by the N symbols, and provides the created symbol block to the encoder 20. The encoder 20 creates a predetermined number of combinations with the N symbols, and delivers the combinations via the N transmission antennas 30-1, 30-2, ⋯, 30-20 N for their corresponding time periods. The time periods indicate symbol durations.

When 4 transmission antennas are used, symbols output from the encoder 20 can be expressed by a 4*4 encoding matrix shown in Equation (1) 25 below.

$$g_{44} = \begin{pmatrix} s_1 & s_2 & s_3 & s_4 \\ -s_2 & s_1 & -s_4 & s_3 \\ -s_3 & s_4 & s_1 & -s_2 \\ -s_4 & -s_3 & s_2 & s_1 \end{pmatrix} \qquad \ldots\ldots (1)$$

In Equation (1), s_1, s_2, s_3, and s_4 are data symbols to be transmitted. Symbols in each column are transmitted for respective time periods, and symbols in each row are transmitted via the respective antennas. Because symbols of one

5 block are transmitted for 4 time periods, the 4 time periods are referred to as "one block duration." Respective columns of the encoding matrix are orthogonal with one another, and this simplifies coding, helps to decoding and obtains maximum diversity gain.

10   FIG. 2 is a block diagram illustrating a conventional receiver for receiving the signal transmitted from the transmitter illustrated in FIG. 1. As illustrated in FIG. 2, the receiver includes M reception antennas 40-1, 40-2, ···, 40-M, a channel estimator 50, a multi-channel symbol arranger 60, and a detector 70.

15   Referring to FIG. 2, the channel estimator 50 estimates channel coefficients indicating channel gains from the transmission antennas 30-1 to 30-N to the reception antennas 40-1 to 40-M, and the multi-channel symbol arranger 60 collects symbols received by the reception antennas 40-1 to 40-M and provides the collected symbols to the detector 70. The detector 70 detects desired

20 symbols by maximum likelihood (ML) decoding, using hypothesis symbols calculated by multiplying the received signals by the channel coefficients.

In the receiver, a received signal x is expressed by Equation (2) below.

$$r_i = \sum_i h_i s_{t,i} + w_t$$

25   . . . . (2)

In Equation (2), t is a symbol duration index (t=0,1,···), and h_i indicates channel gain from an ith transmission antenna to the receiver, and is assumed to be an independent complex Gaussian random variable having a variance of 0.5

per real dimension under flat fading. In addition, $s_{t,i}$ indicates a symbol output via an ith transmission antenna for a tth symbol duration, and w_t is a noise at a tth symbol duration and has an independent zero mean complex Gaussian characteristic having a variance of 1/SNR (Signal-to-Noise Ratio) per complex
5 dimension.

When symbols used during transmission/reception are PSK (Phase Shift Keying) symbols, the symbols are located in a unit circle of a constellation. This means that the symbols are all identical in amplitude. Then, ML decoding of
10 transmitted symbols is equivalent to finding symbols nearest to a linear combination of a received signal r and a channel gain h among all possible symbols.

To decode STBC, information on channel gains is required. When
15 channel characteristic vary fast, it is very difficult to estimate correct information on channel gain, and when a channel characteristic is incorrectly measured, performance of STBC is considerably deteriorated. In order to enable a receiver to effectively estimate a channel characteristic, a transmitter must transmit a training sequence, and the transmission of a training sequence reduces
20 transmission efficiency.

In order to resolve the above-mentioned problem, differential STBC has been developed for which information on a channel characteristic is not required (see H. Jafarkhani, Vahid Tarokh, "Multiple Transmit antenna differential
25 Detection from generalized orthogonal designs," IEEE Trans. on Info.. Theory, Vol. 47, pp. 2626-2631, Sep. 2001).

FIG. 3 is a block diagram illustrating a conventional transmitter using a differential space-time block code (STBC). As illustrated in FIG. 3, the
30 transmitter includes a serial-to-parallel (S/P) converter 105, multipliers 110-1, ⋯,

110-K, an adder 115, a delay 120, an encoder 125, and K transmission antennas 130-1, 130-2, ⋯, 130-K.

Referring to FIG. 3, the S/P converter 105 parallel-converts a previously
5 transmitted symbol block S_v delayed by the delay 120, and outputs K previous symbols $S_{v,1}$, ⋯, $S_{v,K}$. The multipliers 110-1 to 110-K multiply the K previous symbols by information symbols $P_{v+1,1}$, ⋯, $P_{v+1,K}$ to be actually transmitted, respectively, and the adder 115 adds output symbols of the multipliers 110-1 to 110-K, and delivers the result to the delay 120, thereby enabling the result to be
10 multiplied by the next information symbols. Further, the adder 115 provides the added result to the encoder 125. The encoder 125 creates a predetermined number of combinations with output symbols of the multipliers 110-1 to 110-K, and transmits the combinations via the transmission antennas 130-1, 130-2, ⋯, 130-K for the corresponding time periods.
15

An operation of the transmitter will be described with reference to an example where K=4. Initially, the transmitter transmits a particular symbol block $S_1=[s_{1,1}{\sim}s_{1,4}]$ having no information according to the encoding matrix. Thereafter, the transmitter transmits $S_v=[s_{v,1}{\sim}s_{v,4}]$ in the same manner according to the
20 encoding matrix. When information symbols $P_{v+1}=(P_{v+1,1} \cdots P_{v+1,4})$ to be transmitted at a time v+1 are received, a transmission symbol S_{v+1} is determined by Equation (3) below.

$$S_{v+1} = \sum_{k=1}^{4} P_{v+1,k} V_k(S_v)$$

. . . . (3)

25

That is, information symbols to be transmitted at a time v+1 are multiplied by respective symbols of a symbol block $V_k(S_v)$ transmitted at a previous time v, and then added before being transmitted. Here, the information

symbols are a real number created by BPSK (Binary Phase Shift Keying). For the symbol block $V_k(S_v)$, symbol combinations output from the encoder 125 for 4 symbol durations are given by Equation (4),

$$V_1(S_v) = (s_{v,1}, s_{v,2}, s_{v,3}, s_{v,4})^T$$

$$V_2(S_v) = (s_{v,2}, -s_{v,1}, s_{v,4}, -s_{v,3})^T$$

$$V_3(S_v) = (s_{v,3}, -s_{v,4}, -s_{v,1}, s_{v,2})^T$$

$$V_4(S_v) = (s_{v,4}, s_{v,3}, -s_{v,2}, -s_{v,1})^T \qquad \dots\dots\dots (4)$$

where T indicates a transposed matrix.

FIG. 4 is a block diagram illustrating a conventional receiver for receiving a signal transmitted from the transmitter illustrated in FIG. 3. As illustrated in FIG. 4, the receiver includes M reception antennas 150-1, 150-2, ···, 150-M, K delays 155-1,···, 155-K, K multipliers 160-1,···, 160-K, a symbol arranger 165, and a detector 170.

Referring to FIG. 4, the delays 155-1 to 155-K delay signals previously received for one block duration, and output the delayed signals to the multipliers 160-1 to 160-K. The symbol arranger 165 provides the multipliers 160-1 to 160-K with signals received at the reception antennas 150-1 to 150-M from the transmission antennas 130-1 to 130-K for one block duration. The multipliers 160-1 to 160-K calculate substitution signals by multiplying the receive signals by the previously received signals, and provide the calculated substitution signals to the detector 170. The detector 170 detects an information sequence with the substitution signals according to a corresponding modulation scheme.

In order to describe an operation of the receiver, if the received signal shown in Equation (1) is extended for plural block durations, then

$$r_{v,t}=h_1 s_{v,t,1}+h_2 s_{v,t,2}+h_3 s_{v,t,3}+h_4 s_{v,t,4}+w_{v,t} \quad \ldots \ldots (5).$$

In Equation (5), t is a symbol duration index, and v is a block duration
index. In the case of STBC using 4 transmission antennas, one block duration is
comprised of 4 symbol durations. In addition, $w_{v,t}$ is a noise at a tth symbol
duration in a vth block duration. When 4 transmission antennas and the encoding
matrix of Equation (1) are used, Equation (5) can be rewritten as

$$r_{v,1}=h_1 s_{v,1}+h_2 s_{v,2}+h_3 s_{v,3}+h_4 s_{v,4}+w_{v,1}$$

$$r_{v,2}=-h_1 s_{v,2}+h_2 s_{v,1}-h_3 s_{v,4}+h_4 s_{v,3}+w_{v,2}$$

$$r_{v,3}=-h_1 s_{v,3}+h_2 s_{v,4}+h_3 s_{v,1}-h_4 s_{v,2}+w_{v,3}$$

$$r_{v,4}=-h_1 s_{v,4}-h_2 s_{v,3}+h_3 s_{v,2}+h_4 s_{v,1}+w_{v,4} \quad \ldots \ldots (6).$$

By arranging Equation (6), reception signal combinations are created as
follows in Equation (7).

$$R_v^1=(r_{v,1},r_{v,2},r_{v,3},r_{v,4})=(s_{v,1},s_{v,2},s_{v,3},s_{v,4})H_\perp+(w_{v,1},w_{v,2},w_{v,3},w_{v,4})$$

$$R_v^2=(-r_{v,2},r_{v,1},r_{v,4},-r_{v,3})=(s_{v,2},-s_{v,1},s_{v,4},-s_{v,3})H_\perp+(-w_{v,2},w_{v,1},w_{v,4},-w_{v,3})$$

$$R_v^3=(-r_{v,3},-r_{v,4},r_{v,1},r_{v,2})=(s_{v,3},-s_{v,4},-s_{v,1},s_{v,2})H_\perp+(-w_{v,3},-w_{v,4},w_{v,1},w_{v,2})$$

$$R_v^4=(-r_{v,4},r_{v,3},-r_{v,2},r_{v,1})=(s_{v,4},s_{v,3},-s_{v,2},-s_{v,1})H_\perp+(-w_{v,4},w_{v,3},-w_{v,2},w_{v,1}) \quad \ldots (7)$$

The reception signal combination R_v^i is used to detect an ith information
symbol. Here, $H_\perp$ indicates channel characteristics in a matrix form, and is
defined by Equation (8) as follows.

$$H_{\perp} = \begin{bmatrix} h_1 & h_2 & h_3 & h_4 \\ h_2 & -h_1 & -h_4 & h_3 \\ h_3 & h_4 & -h_1 & -h_2 \\ h_4 & -h_3 & h_2 & -h_1 \end{bmatrix} \qquad \ldots\ldots\ldots (8)$$

A product of a reception signal at a time v and a reception signal at a time v+1, i.e., a substitution signal, is determined by Equation (9).

5

$$R\{R^n_{v+1} R^{nH}_v\} = R\{S^T_{v+1} H_{\perp} H^H_{\perp} (V_n (S_v)^T)^H + W_n\}$$
$$= \sum_i^4 |h_i|^2 P_{v+1,n} + R\{W_n\} \qquad \ldots\ldots\ldots (9)$$

In Equation (9), $R\{\cdot\}$ means real conversion, and $(\cdot)^H$ indicates Hermitian transpose. Equation (9) represents a substitution signal for calculating an nth

10 information symbol $P_{v+1,n}$.

According to Equation (9), all elements except the information symbols $P_{v+1,1}$ to $P_{v+1,4}$ are real numbers, and the noise information is already known. On a 4-dimention hyper sphere having each of the information symbols as one axis, if

15 a distance from the origin of the information symbols is identical, a receiver can detect information symbol $P_{v+1,1}$ to $P_{v+1,4}$ even though a value of h indicating a channel characteristic is unknown.

In the conventional transmission/reception system described above,

20 decoding can be performed even though a channel characteristic is unknown. However, symbols in use must be real symbols having the same size. Therefore, in differential STBC technology, transmission symbols are restricted to BPSK symbols. BPSK symbols carry 1-bit information per second per bandwidth (1 bit/hz/sec). However, it is possible to transmit PSK modulation data by grouping

25 transmission symbols by a predetermined number of symbols. For example, it is

possible to group 4 symbols by the 2 symbols and then carry 16PSK modulation data on each symbol group. When 2 symbols transmit 16PSK modulation data in this manner, two 16PSK symbols are transmitted for 4 time periods. As a result, it is possible to carry 2-bit information per second per bandwidth (2 bits/hz/sec).

5

As is well known, M-ary QAM (Quadrature Amplitude Modulation) is more effective than M-ary PSK in view of a signal-to-noise ratio (SNR). In the conventional differential STBC system, PSK must be used even when information of 2 bits or more is carried. Therefore, it is not possible to secure

10 performance improvement attributable to the use of QAM. For example, when 64PSK is used instead of 64QAM, a decrease in SNR accounts to 9.95dB, and this has a fatal effect on the wireless communication system.

SUMMARY OF THE INVENTION

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It is, therefore, an object of the present invention to provide a method for decoding a differential space-time block code (STBC) using channel power in a transmit antenna diversity system.

20 It is another object of the present invention to provide a decoding method being less susceptible to variation and estimation in accuracy of a channel, and having a low SNR loss in a transmit antenna diversity system.

According to one aspect of the present invention, the invention provides

25 a method for encoding information symbols by a differential space-time block code (STBC) and transmitting the encoded information symbols via a plurality of transmission antennas for transmit diversity in a wireless communication system. The method comprises the steps of: receiving one block of information symbols; generating normalized symbols by multiplying the information symbols by one

30 block of previously transmitted transmission symbols and then dividing the

multiplication result by a normalization value, which is determined as a size of the previously transmitted transmission symbols; forming the normalized symbols into a plurality of combinations to transmit the normalized symbols once at each antenna for each time period; and transmitting the combinations via

5 the transmission antennas for a plurality of corresponding symbol durations.

According to another aspect of the present invention, the invention provides a method for receiving information symbols encoded by a differential space-time block code (STBC) before being transmitted and decoding the

10 received information symbols in a wireless communication system. The method comprises the steps of: collecting a signal received at a reception antenna from a plurality of transmission antennas for one block duration; calculating a substitution signal by multiplying the received signal by a signal received for a previous block duration; estimating channel power for a channel from the

15 plurality of transmission antennas to the reception antenna; normalizing the estimated channel power with a normalization value determined as a size of previously received symbols; and calculating information symbols by dividing the substitution signal by the normalized channel power.

20   **BRIEF DESCRIPTION OF THE DRAWINGS**

The above and other objects, features, and advantages of the present invention will become more apparent from the following detailed description when taken in conjunction with the accompanying drawings in which:

25   FIG. 1 is a block diagram illustrating a conventional transmitter using a space-time block code;

FIG. 2 is a block diagram illustrating a conventional receiver for receiving a signal transmitted from the transmitter illustrated in FIG. 1;

FIG. 3 is a block diagram illustrating a conventional transmitter using a

30 differential space-time block code;

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FIG. 4 is a block diagram illustrating a conventional receiver for receiving a signal transmitted from the transmitter illustrated in FIG. 3;

FIG. 5 is a block diagram illustrating a transmitter using a differential space-time block code according to an embodiment of the present invention;

5   FIG. 6 is a block diagram illustrating a receiver for receiving a signal transmitted from the transmitter illustrated in FIG. 5, according to an embodiment of the present invention;

FIG. 7 illustrates symbol error rates (SERs) versus bit energy-to-noise (Eb/No) based on the number L of symbols for estimation of channel power

10   according to an embodiment of the present invention; and

FIG. 8 illustrates a comparison between the conventional technology and the present invention in terms of symbol error rates (SERs) versus bit energy-to-noise (Eb/No).

15   **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT**

Preferred embodiments of the present invention will now be described in detail with reference to the annexed drawings. In the following description, a detailed description of known functions and configurations incorporated herein

20   has been omitted for conciseness. The terms used herein are defined in consideration of their functions in the invention, and can be changed according to a user's intentions, and usual practices. Therefore, the definition should be made based on the overall contents of the specification.

25   The present invention provides a method for decoding a partially coherent space-time block code, which does not require a training sequence, is robust to channel variation, and has a low SNR loss by using only estimated power of a channel in decoding a differential space-time block code (STBC) in a transmit diversity system. The invention can transmit symbols having different

30   distances from the origin on a multidimension hyper sphere.

FIG. 5 is a block diagram illustrating a transmitter using a differential space-time block code according to an embodiment of the present invention. As illustrated in FIG. 5, the transmitter includes a serial-to-parallel (S/P) converter 205, multipliers 210-1, ⋯, 210-K, an adder 215, a delay 220, a normalizer 225, an encoder 230, and K transmission antennas 235-1, 235-2, ⋯, 235-K.

Referring to FIG. 5, the S/P converter 205 parallel-converts a previously transmitted symbol block S_v delayed by the delay 220, and outputs previous symbols $S_{v,1}$, ⋯, $S_{v,k}$. The multipliers 210-1 to 210-K multiply the K previous symbols by information symbols $P_{v+1,1}$, ⋯, $P_{v+1,K}$ to be actually transmitted, respectively, and the adder 215 adds output symbols of the multipliers 210-1 to 210-K, and delivers the result to the delay 220 to multiply the added result by the next information symbols. Further, the adder 215 provides the result to the normalizer 225. Here, the adder 215 is used when the information symbols are grouped by a predetermined number of symbols to transmit PSK or QAM modulation data, i.e., the adder 215 is optional.

The normalizer 225 multiplies the added symbols by a normalization value determined as a reciprocal $1/|S_v|$ of a size of a previous symbol block, and the encoder 230 creates a predetermined number of combinations with an output of the normalizer 225 according to a predetermined transmission encoding matrix, and transmits the combinations via the transmission antennas 235-1, 235-2, ⋯, 235-K for the corresponding time periods.

An operation of the transmitter will be described with reference to an example where 4 transmission antennas and the encoding matrix of Equation (1) are used. Initially, the transmitter transmits a particular symbol block $S_1=[s_{1,1} \sim s_{1,4}]$ having no information according to the encoding matrix. When

information symbols $P_{v+1}=(P_{v+1,1} \cdots P_{v+1,4})$ to be transmitted at a time $v+1$ are received, a transmission symbol S_{v+1} is determined by Equation (10) below.

$$S_{v+1} = \sum_{k=1}^{4} P_{v+1,k} \frac{V_k(S_v)}{|S_v|}$$
$$= \sum_{k=1}^{4} \frac{P_{v+1,k} V_k(S_v)}{\sqrt{|s_{v,1}|^2+|s_{v,2}|^2+|s_{v,3}|^2+|s_{v,4}|^2}} \quad \cdots \cdots (10)$$

5

That is, information symbols are multiplied by a symbol block $V_k(S_v)$ transmitted at a previous time, and then transmitted after being normalized. Here, a symbol block $V_k(S_v)$ transmitted for a kth symbol duration in a vth block duration is determined by Equation (11).

10

$$V_1(S_v)=(s_{v,1},s_{v,2},s_{v,3},s_{v,4})^T$$
$$V_2(S_v)=(s_{v,2},-s_{v,1},s_{v,4},-s_{v,3})^T$$
$$V_3(S_v)=(s_{v,3},-s_{v,4},-s_{v,1},s_{v,2})^T$$
$$V_4(S_v)=(s_{v,4},s_{v,3},-s_{v,2},-s_{v,1})^T \quad \cdots \cdots (11)$$

15

Normalizing a transmission symbol block with a size $|S_v|$ of a previous symbol block in a transmitter prevents deterioration of detection performance in a receiver caused by power variation of transmission symbols.

20   FIG. 6 is a block diagram illustrating a receiver for receiving a signal transmitted from the transmitter illustrated in FIG. 5, according to an embodiment of the present invention. As illustrated in FIG. 6, the receiver includes M reception antennas 305-1, 305-2, $\cdots$, 305-M, delays 310-1,$\cdots$, 310-K, multipliers 315-1,$\cdots$, 315-K, a symbol arranger 320, dividers 325-1,$\cdots$, 325-K, a

25 power estimator 330, a normalizer 335, and a detector 340.

Referring to FIG. 6, the delays 310-1 to 310-K delay signals previously received for one block duration, and output the delayed signals to the multipliers 315-1 to 315-K. The symbol arranger 320 provides the multipliers 315-1 to 315-

5   K with signals received at the reception antennas 305-1 to 305-M from the transmission antennas 235-1 to 235-K for one block duration. Here, one block duration is comprised of K symbol durations. The multipliers 315-1 to 315-K calculate substitution signals by multiplying the receive signals by the previously received signals.

10

The power estimator 330 calculates total power of channels with received signals, rather than calculating channel gains indicating channel characteristics from the K transmission antennas 235-1 to 235-K to the reception antennas 305-1 to 305-M. The normalizer 335 then multiplies the channel power

15   by a normalization value determined as a size of previous reception power, and the dividers 325-1 to 325-K detect information symbols by dividing the substitution signals by the normalized channel power. The detector 340 detects an information sequence with the detected information signals according to a corresponding modulation scheme.

20

As described above, the receiver enables reliable decoding even when the information symbols are different in size, by removing an influence caused by channel characteristics from the received signals with the estimated channel power. Actually, channel power from the transmission antennas to the receiver

25   can be expressed as shown in Equation (12).

$$h_1 h_1^* + h_2 h_2^* + ... h_K h_K^* \qquad \ldots \ldots (12)$$

In Equation (12), h_k indicates a channel gain from a kth transmission

antenna to the receiver. Because h_k is an independent complex Gaussian random variable, the channel power follows chi-square distribution, a freedom degree of which is 2K. Then, the channel estimator 330 can calculate an estimation value of the channel power through autocorrelation of the received signal in accordance

5 with Equation (13).

$$\hat{P}_B = E\{r^*_{v+1,i} r_{v+1,i}\} = \sum_{i=1}^{4} |h_i|^2 + \sigma^2_w \qquad \ldots\ldots\ldots (13)$$

As described above, because v is a block duration index and i is a

10 transmission antenna index, $r_{v+1,i}$ is an ith signal received for a $(v+1)^{th}$ block duration. Likewise, h_i is a channel gain from an ith transmission antenna, and σ^2_w is a noise variance.

In another case, by empirical autocorrelation, channel power is

15 calculated using Equation (14).

$$\hat{P}_B = \frac{1}{L} \sum_{j=1}^{L} \sum_{i=1}^{4} r^*_{v+j-\frac{L}{2},i} r_{v+j-\frac{L}{2},i} \qquad \ldots\ldots\ldots (14)$$

In Equation (14), L indicates the number of symbols used for estimation

20 of channel power, i.e., indicates a length of symbol duration. Further, Equation (14), unlike Equation (13), more accurately estimates channel power using signals received for predetermined symbol durations rather than one block.

Information symbols $P_{v+1,1}$ to $P_{v+1,4}$ at a time v+1 are calculated by a

25 reception signal at a time v and a reception signal at a time v+1. More specifically, reception signals are expressed as Equation (6) above, and reception signal combinations are created using the reception signals by the symbol

arranger 320 in accordance with Equation (7). As described above, noise information is already known.

In order to detect information symbols, the multipliers 315-1 to 315-K calculate substitution signals by multiplying previously received signals provided from the delays 310-1 to 310-K by the currently received signals from the symbol arranger 320. The substitution signals are expressed in Equation (15).

$$R\{R_{v+1}^{n}R_{v}^{nH}\} = \sum_{i=1}^{4}|h_{i}|^{2}\sqrt{\sum_{i=1}^{4}|s_{v,i}|^{2}}P_{v+1,n}+R\{W_{n}\} \qquad \ldots \ldots (15)$$

In Equation (15), R{·} means real conversion, and $(\cdot)^{H}$ indicates Hermitian transpose. Equation (15) represents a substitution signal for calculating an nth information symbol $P_{v+1,n}$.

The square root term is a normalization value used to cope with channel variation, and is calculated using an autocorrelation of a previous reception signal and an estimation value of the channel power, or using the previous reception signal itself. An autocorrelation value of a previous reception signal is defined in Equation (16).

$$R\{R_{v}^{n}R_{v}^{nH}\} = \left(\sum_{i=1}^{4}|h_{i}|^{2}\right)\left(\sum_{i=1}^{4}|s_{v,i}|^{2}\right)+R\{W_{n}\} \qquad \ldots \ldots (16)$$

That is, the normalization value is calculated by dividing Equation (16) by the channel power and then taking a square root. Then, the normalizer 335 outputs normalized channel power by multiplying the channel power by the normalization value, and the dividers 325-1 to 325-K output information symbols $P_{v+1,i}$ by dividing outputs of the multipliers 315-1 to 315-K, expressed as Equation (15), by the normalized channel power. The detector 340 restores an

information sequence with the information symbols according to a corresponding modulation scheme.

The present invention easily detects information symbols even when the
5 information symbols have different distances from the origin. For example, when 2 QAM modulation data symbols were transmitted through P_1 to P_4, the detector 340 is comprised of 2 QAM demodulators, and restores an information sequence with the 2 QAM modulation data symbols. When QAM is used in this way, an SNR loss can be minimized as compared with when PSK is used, and a receiver
10 for decoding information symbols is simple in structure and various modulation schemes can be used.

FIG. 7 illustrates symbol error rates (SERs) versus bit energy-to-noise (Eb/No) based on the number L of symbols for estimation of channel power
15 according to an embodiment of the present invention. Reference numeral 410 indicates performance for an ideal case where accurate channel power is known. Reference numerals 420 to 450 indicate performances determined using channel power estimated when L is 100, 50, 25 and 10, respectively. As illustrated in FIG. 7, it is noted that performance for the case where L is sufficiently long is not that
20 different from the performance for the ideal case.

In order to analyze performance according to the present invention, a comparison will be made between a conventional case (hereinafter referred to as "first case") where of 4 information symbols, P_1 and P_2 are grouped to transmit
25 one 16PSK modulation symbol, and P_3 and P_4 are grouped to transmit one 16PSK modulation data, and a proposed case (hereinafter referred to as "second case") where 16QAM modulation data is transmitted according to the present invention. Herein, in order to secure fairness of comparison, Equation (14) that does not use a training sequence was used when channel power was estimated
30 according to the present invention.

FIG. 8 illustrates a comparison between the first case and the second case in terms of symbol error rates (SERs) versus bit energy-to-noise (Eb/No). Reference numeral 560 indicates performance for the case where 16QAM

5 modulation data is decoded according to the present invention when accurate channel power is not known. Reference numeral 550 indicates performance for the case where 16QAM modulation data is decoded using estimated channel power. Reference numeral 540 indicates performance for the case where 16PSK modulation data is decoded using the conventional differential STBC. Reference

10 numeral 530 indicates performance for the case where 64QAM modulation data is decoded using accurate channel power. Reference numeral 520 indicates performance for the case where 64QAM modulation data is decoded using estimated channel power. Reference numeral 510 indicates performance for the case where 64PSK modulation data is decoded using the conventional differential

15 STBC.

As illustrated in FIG. 8, the present invention can obtain a power gain of 6.2dB at the same symbol error rate (SER), and this means that it is possible to reduce power of 6.2dB in achieving the same symbol error rate. That is,

20 performance reduction caused by an estimation of channel power is at a negligible level.

The present invention has a number of advantages when compared to the prior art. That is, the present invention can obtain SNR gain, because the

25 invention enables transmission/reception being robust to fast fading , does not require a training sequence for channel estimation, and can transmit modulation symbols having different distances from the origin.

While the present invention has been shown and described with reference

30 to a certain preferred embodiments thereof, it will be understood by those skilled

in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention as defined by the appended claims.